COMPACT MARX GENERATOR FOR REPETITIVE APPLICATIONS

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Abstract

We designed a compact repetitive Marx generator. The Marx generator contains 25 stages consisted with capacitor banks and spark gap switches. We used door knob ceramic capacitors. The capacitors are charged through inductors by a capacitor charging power supply. The length and the diameter of the Marx generator are about 150 cm and 60 cm, respectively. We conducted a preliminary test at the condition of low charging voltage using nitrogen gas. We present the characteristic of the Marx generator and discuss the design issues such as high voltage insulation.

I. INTRODUCTION

Marx generator is widely used in pulsed power systems generating high voltages up to several MV. In order to expand the applications of Marx generators, it is important to develop a compact and repetitive one.

For the purpose of compactness of a Marx generator, the structure of that is specially designed. Since capacitors and switches occupy most volume of a Marx generator, the arrangement of those is key point in design of a compact one. Repetitiveness of Marx generator is limited by switches and charging units. Spark gap switches, which are generally used in Marx generators, have a limitation in repetition rate for its recovery characteristics according to medium gas condition. The charging units limit the maximum charging rate at a given charging power supply.

We designed a Marx generator which is able to be operated in repetitive mode. The size of the Marx generator is small considering the maximum output voltage capability. We present the design features of the Marx generator and discussed the several kinds of output characteristics of it.

II. DESIGN

Fig. 1 shows the basic Marx generator circuit during charging time. Each stage, which consists of a capacitor bank, resistors and a switch, is connected in parallel during charging. The capacitors are charged through the charging resistors by a high voltage charging power supply

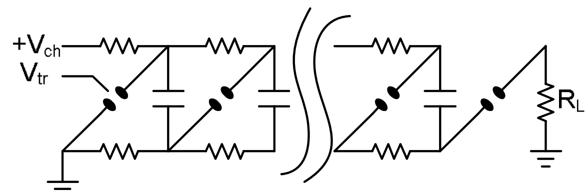

Figure 1. The basic Marx generator circuit.

.When the switches are turned on, the stages are connected in series, and then the voltage charged each capacitor is added. The voltage at the output switch is theoretically given by

$$V_o = NV_{ch}. \quad (1)$$

Here N is number of stages, and V_{ch} is charging voltage.

The Marx generator is simply approximated as a RLC circuit at discharging mode. The equivalent capacitance of the Marx generator is given by

$$C_{eq} = C_n / N, \quad (2)$$

where C_n is the capacitance of a stage.

When the equivalent inductance of a Marx generator is L_{eq}, the equivalent impedance of the Marx generator is calculated from the equation:

$$Z_M = \sqrt{C_{eq} / L_{eq}} \quad (3)$$

When the Marx impedance is half of the load impedance R_L, the load voltage is about 70 % of NV_{ch}.

Since the charging voltage, however, is distributed not only to the charging capacitors, but also to the intrinsic and stray capacitance of the switch as shown in Fig. 2, the voltage multiplication across the switch gap is lower than the theoretical value.

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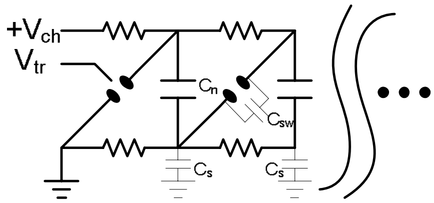

Figure 2. The capacitive components in a Marx generator.

The voltage difference between the gaps of the second switch is given by

$$\Delta V = V_{ch}\left(1 + \frac{C_s}{C_s + C_{sw}}\right) \qquad (4)$$

Fig. 3 is the schematic of the cross- section of the designed Marx generator. We used ceramic doorknob capacitors (TDK 2.1 nF, 50 kV) as energy storage capacitors. Since each stage consists of 4 capacitors, and the number of stages is 25, total 100 capacitors are used in the Marx generator. We arranged the capacitors in zigzag form. The zigzag configuration helps to minimize the length of the Marx generator since the required insulation distance between stages is intrinsically obtained as the length of capacitor. This can be recognized from Fig. 3.

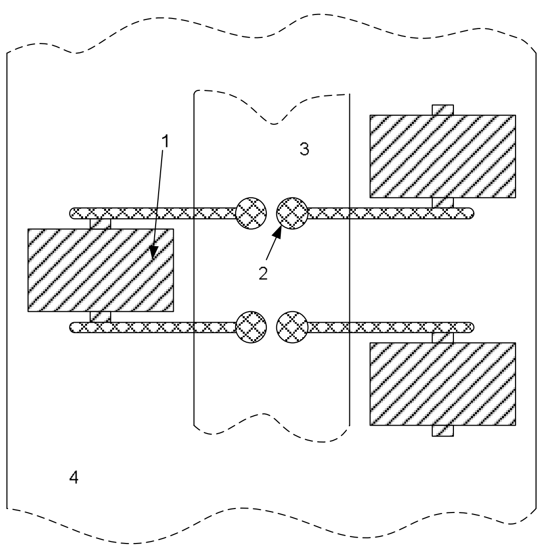

Figure 3. Cross-sectional schematic of the Marx generator. (1: Capacitor, 2: Switch, 3: Switch tube, 4: Gas Tank)

The spark gap switch is located along the center axis. A 10 mm diameter brass ball is used as the electrode of the spark gap switch. The gap distance is about 7 mm. The spark gap switches are housed in a polycarbonate tube, which separates the gas in the switch tube from that in the tank. The gas in the switch tube flow in order to reduce the recovery time of the switch breakdown strength. The tank is filled with high pressure SF_6 or nitrogen gas for insulation.

It is important to enhance the trigger ability of the Marx generator. With the aligned spark gap switch configuration as shown in Fig. 3, UV light generated from the early discharged switch gap illuminates following switch electrodes. The UV helps to develop a self breakdown between the spark gap. According to the Eq. (4), the gap voltage can be raised by increasing the stray capacitance to the ground. We inserted additional capacitors at first two stages to ensure over-voltage development across the first two spark gaps. These improve the reliable triggering of the Marx generator.

Fig. 4 is the photograph of the Marx generator. The height of the Marx generator is about 1.5 m. The pressure tank is made from SUS304, and its diameter is about 60 cm. A capacitive voltage probe is installed near the end of the Marx generator. Since this capacitive voltage probe works in differential mode, we integrated the measured signal by using the internal function of the digital storage oscilloscope LeCroy WaveRunner 6050.

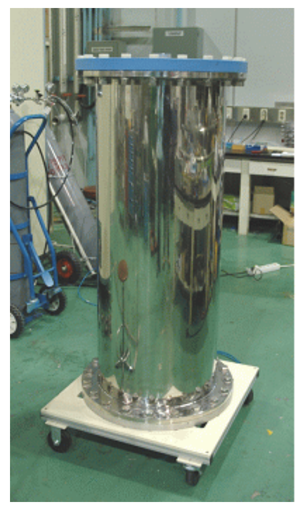
Figure 4. Photograph of the Marx generator.

III. TEST RESULTS

Fig. 5 is the waveform of the current at short circuit condition. The current was measured with a Stangenens CT (0.05V/A). The stage charging voltage is 10 kV. The switch tube was pumped to trigger the Marx generator. The first period of the current is about 200 ns. Considering the RLC model for the Marx generator, we calculated the equivalent Marx inductance and Marx impedance from the Eq. (2) and (3). The Marx inductance and Marx impedance are 3 μ H and 95 Ω , respectively.

We tested high voltage output characteristics by using a 5 cm long air gap as a load. Fig. 6 is the result for the test, when the charging voltage is 10 kV. Ch1 is the signal from the differential capacitive probe. F1, the integrated waveform of Ch1, is the voltage signal, whose sensitivity is 1.8 kV/nVs. The measured peak voltage is 237 kV, which corresponds the voltage conversion efficiency of about 90% at open load.

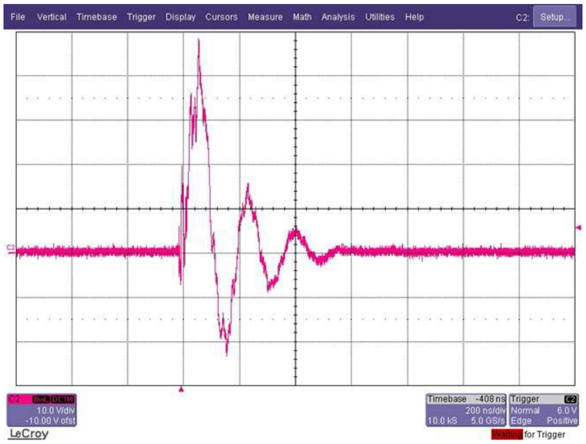

Figure 5. Short circuit current for the Marx generator.

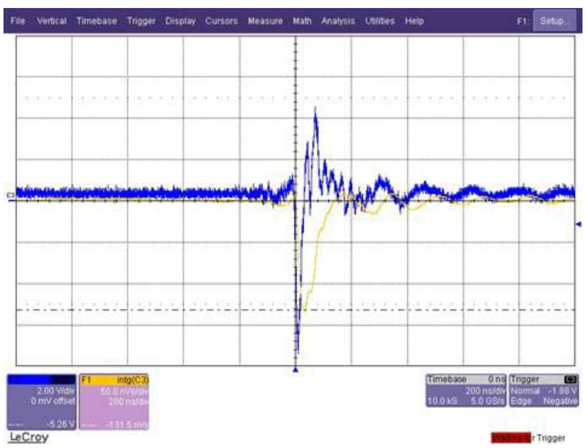

Figure 6. Typical waveform of capacitive voltage probe at 25 Ω load condition.

We tested repetitive operation mode of the Marx at 10 kV charging voltage. Fig, 7 is a typical result when the Marx generator was operated in the burst mode of 10 Hz pulse repetition rate, 1second burst length, and 10 second burst period. The power supply's maximum output power is 8 kJ/s. We used a voltage reversal protection circuit using a freewheeling diode and two noninductive resistors. We are under testing at higher repetition rate and higher charging voltage operating condition.

Figure 7. Charging voltage waveform at bust mode operation..

IV. SUMMARY

We have designed 1.5 m height, 60 cm diameter, Marx generator. The Marx generator is compact in size and repetitive in operation. The test results say that the voltage conversion efficiency at open load is about 90 %, and Marx impedance is about 95 Ω . The Marx generator is well triggered at low charging voltage condition and repetitive operating mode. We expect that the Marx generator can be used in many repetitive high voltage applications.

V. REFERENCES

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